1999-2002 ABSTRACT AND KEYWORD INDEX

Journal of Manufacturing Processes
Volume 1, Number 1, 1999

Excimer Pulsed Laser Ablation of Polymers in Air and Liquids for Micromachining Applications, T-C. Chang, P.A. Molian, v1, n1, 1999, pp1-17

Micromachining of polymers is an important field that has both immediate and future applications in diverse fields such as medicine, microelectromechanical systems, and photonics. In this work, ultraviolet pulsed laser ablation of polymethyl methacrylate (PMMA), polypropylene (PP), and polyethylene (PE) was performed using a KrF (krypton-fluorine) excimer laser in air, methanol, and ethyl alcohol. The size of the hole and etch depth were marginally increased in PMMA but were markedly reduced in PP and PE by the organics. There are other beneficial and detrimental effects of the organics in regard to the taper of the hole, contamination, thermal damage, and cracking that are explained based on laser-liquid-polymer interactions, which include self-focusing, chemical reactions, pressure-wave generation, and thermal quenching. Existing polymer ablation models were used to describe the observed etch depth versus incident laser energy fluence.

Keywords: Ablation, Pulsed Laser, Polymer, Micromachining

Non-Iterative Control of Small-Radius Bend Angle, Kerry L. Elkins, Robert H. Sturges, v1, n1, 1999, pp18-30

Controlling first-part quality in small-radius press brake bending operations is motivated by the need to produce small-lot parts of high quality. A new technique for angle control has been developed based on an experimentally measured model of material properties, tooling geometry variables, and on-line measurements of part deformation. This technique requires the off-line measurement of part thickness and hardness, plus the online measurement of loaded angle and press ram position. Linear regression and neural network techniques are compared to develop a robust model of springback. A control scheme is introduced that provides accurate first-part bend angles for small-lot sheet metal manufacture.

Keywords: Bending, Springback, Press Brake, Automation, Manufacturing

In-Process Joint Strength Estimation in Pulsed Laser Spot Welding Using Artificial Neural Networks, Dae-Cheol Lim, Dae-Gab Gweon, v1, n1, 1999, pp31-42

Pulsed laser spot welding is used in the manufacture of many goods. Because weak joints can lead to product defects, it is important to monitor and control the joint strength precisely. This paper introduces a method to estimate the joint strength of spot welds during the welding process. A point infrared sensor is used to measure temporal radiation on the top face of the spot weld. Because variable measuring conditions affect the radiation power, a scale-free radiation feature is extracted from the measured radiation and used as a monitoring criterion. An artificial neural network (ANN) uses this feature to estimate joint strength. In experiments, significant welding parameters are varied within a controllable range, and 640 weld parts are used for ANN learning. The correlation coefficient between the estimated and measured strength is more than 0.98 for learned parts. Another 180 weld parts are used to appraise the efficiency of the learned ANN, and the mean square error of estimation is 0.78 kgf.

Keywords: Pulsed Laser Spot Welding, Infrared Sensor, In-Process Quality Monitoring, Artificial Neural Network, Nd:YAG Laser

Striation Formation and Melt Removal in the Laser Cutting Process, Kai Chen, Y. Lawrence Yao, v1, n1, 1999, pp43-53

The mechanisms of melt ejection and striation formation in continuous wave laser cutting of mild steel are discussed. Melt ejection from the cutting front is shown to be a cyclic phenomenon. Striation formation is strongly affected by the oscillatory characteristic of the thin liquid film on the cutting front during melt ejection, together with the oxidation and heat transfer process. Cutting speed determines whether the liquid film will rupture or generate waves on the cutting front. Theoretical explanations are given according to the instability theory of a thin liquid film in a high-velocity gas jet and the diffusion-controlled oxidation theory. Striation frequency and depth are predicted according to the above theories. Experimental investigations were carried out and the results are consistent with the calculations. The better understanding has shed light on further investigations and optimal process development.

Keywords: Laser Cutting, Striation, Oxidation, Instability

A Study on Torch Path Planning in Laser Cutting Processes, Part 1: Calculation of Heat Flow in Contour Laser Beam Cutting, Guk-chan Han, Suck-joo Na, v1, n1, 1999, pp54-61

Conductive heat transfer in contour laser beam cutting is analyzed by using a transient, two-dimensional finite difference model, and the result is combined with a simple analytic model. From the calculation results, the correlation is derived between workpiece temperature and opening angles at a corner in contour cutting.

1999-2002 abstract and keyword index

As a result, a modified analytic solution is developed to predict if excessive workpiece heating occurs for given cutting contours in a nested plate. The main objective is to use the computation results in the optimization of torch path planning to provide fully automated CNC programming software for laser cutting. To efficiently apply the analytic model in torch path planning, the critical temperature that should be avoided during the cutting sequence is considered. This leads to an improvement of the cutting quality in the automatic cutting process.

Keywords: Contour Laser Beam Cutting, Finite Difference Method, Nonstationary State Heat Conduction, Opening Angle, Critical Temperature, Torch Path Planning

A Study on Torch Path Planning in Laser Cutting Processes, Part 2: Cutting Path Optimization Using Simulated Annealing, Guk-chan Han, Suck-joo Na, v1, n1, 1999, pp62-70

In Part 1 of this paper, the heat flow in contour laser beam cutting was calculated by using the finite difference model, and a modified analytic model was developed based on the numerical experiments. Part 2 addresses the problem of optimal torch path planning for the 2-D laser cutting of a stock plate nested with irregular parts. Under the constraint of the relative positions of parts enforced by nesting, the optimization algorithm generates a feasible cutting path. The simulated annealing technique is adopted for solving the torch path optimization problem to minimize a specified cost function. The objective is to traverse the cutting contours with a minimum path length and, at the same time, to minimize the effect of heat on the cutting path sequence. To minimize the heat effect and avoid overheating, the critical temperature that should be avoided during the whole cutting sequence is considered. In this way, a global solution can be obtained in a reasonable time. Several examples are presented to illustrate the effectiveness of the proposed method.

Keywords: Laser Beam Cutting, Torch Path Planning, Simulated Annealing, Cost Function, Critical Temperature

Material Removal Rate in Flat Lapping, Xiaobin Le, M.L. Peterson, v1, n1, 1999, pp71-78

Lapping is a critical technology in a number of precision manufacturing applications. Previous research has focused primarily on mechanisms of material removal and the effects of input variables on material removal rate (MRR). The behavior of MRR in lapping processes when the standard input variables—workpiece pressure, relative velocity of workpiece and lap, and relative material and abrasive hardness—are carefully controlled has not been extensively explored. Exploration of this controlled-condition situation is important because of its prevalence in production environments. Experimental data presented here show that the MRR for lapping is not constant, but instead it varies with time and can be described as a random variable. In general, mean MRR decreases with time. A preliminary description is presented that shows the behavior of MRR with time. The removal of waste slurry from the lapping plate is shown to be a critical issue for the design of the lapping plate and the lapping procedure.

Keywords: Lapping, Polishing, Chem-Mechanical Planarization, Electronic Materials

Journal of Manufacturing Processes Volume 2, Number 1, 2000

Multiaxis Machining: PKMs and Traditional Machining Centers, Irene Fassi, v2, n1, 2000, pp1-14

Since the first CNC-type hexapod machine tool prototypes were presented at the 1994 International Machine Tool Show (IMTS) in Chicago, much debate has ensued on whether or not these machine tools will ever reach the place where they challenge traditional machining centers. This paper presents a review of research topics in the field of parallel kinematic machining for manufacturing, as well as a parallel view of the state of the art of traditional multiaxis machining. After discussing similarities as well as differences in issues faced by parallel kinematic machines (PKMs) and traditional machining centers, a survey of existing prototypes is provided.

Keywords: Parallel Kinematic Machines, Machining, PKM, Machine Tools, Five-Axis Machining, Multiaxis Machining

Estimation of Maximum Allowable Step Length for Five-Axis Cylindrical Machining, Yean-Ren Hwang, Min-Tse Ho, v2, n1, 2000, pp15-24

Five-axis cylindrical machining is the only way to machine some complicated sculptured surfaces, such as the wheel surfaces of turbo compressors. Current computer-aided manufacturing (CAM) algorithms for five-axis cylindrical machining only consider the surfaces' geometric information when generating cutter contact points (CC points). Hence, the step length, which is the distance between two CC points, is determined only by the surface parameters for these CAM algorithms. Because of tool-axis rotation, the actual cut trajectory within each step is no longer a straight line passing through two consecutive CC points for five-axis machining. Thus the cut error and

1999-2002 abstract and keyword index

the maximum allowable step length should depend on the structural parameters of NC machines as well as the surface's geometry. This paper develops a new algorithm to estimate the maximum allowable step length based on the cut error of five-axis cylindrical machining, and shows that this algorithm provides better estimation than traditional algorithms.

Keywords: Step Length, Five-Axis NC, Tool Path Generation, Cylindrical Machining

Ruled Surface Machining on Five-Axis CNC Machine Tools, Rong-Shine Lin, Yoram Koren, v2, n1, 2000, pp25-35

To achieve high precision and high productivity in machining sculptured surfaces, a new architecture for a five-axis CNC interpolator for machining ruled surfaces was developed and demonstrated on a milling machine. The objective of the five-axis interpolator is to continuously maintain the milling cutter axis in parallel with the straight lines of the ruled surface. The cutter position and orientation are calculated at each sampling period of the interpolator, and corresponding axial position commands are generated by an inverse kinematics algorithm. This real-time approach produces precise surfaces and requires substantially less machining time compared to the conventional off-line approach. Two new g-codes are also given in this paper for the new interpolator to produce part surfaces in CNC milling machines.

Keywords: Five-Axis Machining, Five-Axis CNC, Ruled Surface, Computer Control

Kinematic Synthesis of Hexapods with Specified Orientation Capability and Well-Conditioned Dexterity, Tian Huang, Jinsong Wang, Clement M. Gosselin, David J. Whitehouse, v2, n1, 2000, pp36-47

This paper systematically investigates issues relevant to the kinematic synthesis of hexapod-based machine tools. Based on a full understanding of the geometrical characteristics of workspace boundary, the concept of a prescribed workspace having a given orientation capability is defined. Two performance measures are presented—the local dexterity and workspace radius ratio. The closed-form solution to these measures is formulated by means of singular value decomposition and differential geometry. The influences of the fundamental design parameters on the performance indices are discussed, resulting in an optimal design having no strut interference. An example of application to the kinematic design of a prototype hexapod is given to illustrate the effectiveness of this approach.

Keywords: Hexapods, Parallel Manipulators, Optimal Design, Workspace, Dexterity

Parallel Kinematic Machine Positioning Accuracy Assessment and Improvement, Jing Song, Jong-I Mou, Calvin King, v2, n1, 2000, pp48-58

Although parallel kinematic machines potentially offer high force/torque capacity, structural rigidity, speeds, and dexterity, characterization of the first generation of hexapods has proven the need for improving the positioning accuracy before these new machines will be accepted for manufacturing applications. This paper proposes a systematic approach to assess the accuracy of a parallel kinematic machine subject to structural errors and then to effectively compensate for them. Analytical models were constructed for both the nominal and actual structures. Sensitivity analysis was performed, and it was determined that of the 33 sources of error, only the six due to strut length deviations are significant. Simulations indicate that the accuracy of strut length calculations shows a discrepancy of at most ±4 micrometers. In summary, the simulation and preliminary experimental results show that the performance of parallel kinematic machines can be enhanced through error modeling and compensation.

Keywords: Parallel Kinematic Machine, Error Assessment, Error Modeling, Error Compensation

Comparison of Parallel Structure Concepts for Five-Axis Machining, Reimund Neugebauer, Frank Wieland, Steffen Ihlenfeldt, v2, n1, 2000, pp59-66

Parallel structures are characterized by closed kinematics chains. Compared with conventional structures, which have serially arranged axes and are thus characterized by open kinematics chains, parallel structures have a variety of advantages. These primarily include lower moved mass, high dynamics, the high number of possible repeating parts, and the advantageous integration of measures in the control system that are relevant to accuracy. The following presentation classifies parallel structures with six degrees of freedom according to the type of drive used. Based on free-form surface machining in die and mold making, kinematics requirements will be explained and various concepts regarding kinematics, structure loading, and stiffness will also be discussed. Finally, a preferable solution will be provided in the summary.

Keywords: Machine Tool, Parallel Kinematic Machines (PKM), Hexapod, Die and Mold Making

A Comparison of Stiffness Characteristics of Serial and Parallel Machine Tools, Jiri Tlusty, John C. Ziegert, Shannon Ridgeway, v2, n1, 2000, pp67-76

The stiffness characteristics of classical serial machine tools are compared with parallel kinematic, or hexapod,

1999-2002 abstract and keyword index

structures for high-speed milling applications. A structural stiffness requirement for this application is determined by the stiffness of current-generation high-speed spindles and the desire for stability against chatter. It is found that hexapod structures exhibit lower structural stiffness than can be achieved in serial machines using the same drive components. Furthermore, the stiffness varies widely across the workspace of hexapod machines, leading to difficulties in control and limiting achievable accuracy. Theoretically derived stiffnesses are compared with experimentally measured stiffnesses for two hexapod machines and are found to show good agreement.

Keywords: Hexapod, Stiffness, Machine Tool, Platform

Journal of Manufacturing Processes Volume 2, Number 2, 2000

Thermal Characterization of the Chip-Tool Interface When Using Coated Turning Inserts, W. Grzesik, P. Nieslony, v2, n2, 2000, pp79-87

This paper reports some results of extensive experimental investigations of the thermal interactions between the coating/substrate and the moving surface of th. chip. Semi-orthogonal cutting when bar turning a medium carbon steel and an austenitic stainless steel was carried out. Both flat-faced and grooved inserts coated with TiC, TiC/TiN, and TiC/Al_2O_3/TiN were tested. A standard K-type thermocouple embedded in the workpiece was used to convert measured efm's to the interfacial temperatures. In addition, the chip-rake contact length and the area of contact were determined by using computer processing of scanned contact images. The minimum steady-state temperature at the interface between the moving chip and the coating-substrate system was explained in terms of the heat flux intensity and the thermal properties of both components of a unique closed tribo-system.

Keywords: Bar Turning, Coating, Tribo-Contact, Thermal Characteristics

Process Planning for On-Line Consolidation in Tape Winding of Noncircular Thermoplastic Composites, M. Atif Yardimci, Christoph M. Pistor, Selcuk I. Guceri, v2, n2, 2000, pp88-99

On-line consolidation of thermoplastic composites proved feasible to fabricate high-quality precision parts using pre-impregnated tapes as the building material and lasers as the heat source (laser-assisted tape winding [LATW]). The narrow LATW operation windows for the thermoplastic matrix materials of engineering interest necessitate careful process planning. Noncircular cross-section parts pose additional challenges. In this work, a general planning methodology was developed and implemented into process planning software to produce structurally sound thermoplastic composite parts with LATW. The methodology includes geometry definition, mandrel trajectory, winding speed prediction, and calculation of required laser power. Thin and thick-walled test cases were studied. Parametric studies assessed the variation of required laser power distribution vs. process parameters (mandrel rotation speed, winding speed, and part geometry). The software also assessed manufacturability with the positive, definite winding speed constraint. It was determined that the winding speed may become negative when producing high-aspect ration elliptical rings on the current prototype configuration, resulting in unwinding and/or tape buckling.

Keywords: On-line Consolidation, Composites, Thermoplastic, Tape Winding, Planning

An Analytical Prediction of Flange Wrinkling in Sheet Metal Forming, Xi Wang, Jian Cao, v2, n2, 2000, pp100-107

Wrinkling is one of the major defects in sheet metal forming. The ability to accurately predict the occurrence of wrinkling is critical to the design of tooling and processing parameters. An analytical approach for predicting the onset of flange wrinkling is presented. This method is based on the wrinkling criterion proposed by Cao and Boyce for predicting the buckling behavior of sheet metal under normal constraint. Using a combination of energy conversation and plastic bending theory, the analysis provides the critical buckling stress and wavelengths as functions of normal pressure. The results are in excellent agreement with those obtained from Cao and Boyce's numerical approach, and also match well with the experimental results of a square cup forming. In addition, the effects of material properties on the wrinkling behavior are also discussed. The analytical method significantly reduces computational time and is suitable for direct engineering application.

Keywords: Flange Wrinkling, Energy Method, Plastic Bending, Sheet Metal Forming

Experimental Evaluation of Cutter Orientation When Ball Nose End Milling Inconel 718™, E-G Ng, D.W. Lee, R.C. Dewes, D.K. Aspinwall, v2, n2, 2000, pp108-115

High-speed machining (HSM), specifically end milling and ball end cutting, is attracting interest in the aerospace industry for the machining of complex 3-D aerofoil surfaces in titanium alloys and nickel-based superalloys.

1999-2002 abstract and keyword index

Following a brief introduction on HSM and related aerospace work, the paper reviews published data on the effect of cutter/workpiece orientation, also known as engagement or tilt angle, on tool performance. Such angles are defined as $\pm\beta_{fN}$ and and $\pm\beta_f$.

Experimental work is detailed on the effect of cutter orientation on tool life, cutting forces, chip formation, specific force, and workpiece surface roughness when high-speed ball end milling Inconel 718™. Dry cutting was performed using 8 mm diameter PVD-coated solid carbide cutters with the workpiece mounted at an angle of 45 degrees from the cutter axis.

A horizontal downward $-\beta_{fN}$ cutting orientation provided the best tool life with cut lengths approx. 50% longer than for all other directions $+\beta_{fN}$, $+\beta_f$, and $-\beta_f$. Evaluation of cutting forces and associated spectrum analysis of results indicated that cutters employed in a horizontal downward direction produced the least vibration. This contributed to improved workpiece surface roughness, with typical mean values of approx. 0.4 mu-m Ra as opposed to approx. 1.25 mu-m Ra when machining in the vertical downward ($-\beta_f$) direction.

Keywords: High-Speed Milling, Cutting Forces, Chip Formation, Surface Roughness, Nickel-Based Superalloy

Tool Path Planning for Avoiding Exit Burrs, Chih-Hsing Chu, David Dornfeld, v2, n2, 2000, pp116-123

Milling exit burrs usually form along the edges of a workpiece when the tool leaves the part while removing stock material. One of the most efficient methods for minimizing exit burrs is to prevent the tool from exiting the workpiece during material removal. This paper describes a systematic framework to generate tool paths that always enter a part, which is not a thin structure, in a planar milling operation. Three distinct tool exit conditions are analyzed for polygonal parts. A test criterion is then proposed to examine the occurrence of tool exits. For each condition, a tool path planning scheme is developed to avoid tool exits. These schemes are proved to be effective using the test criterion. This work is integrated into a networked manufacturing environment as a burr agent. Test parts are cut to demonstrate that this framework enhances edge quality by minimizing tool exits.

Keywords: Burr, Tool Exit, Tool Path, Milling, Edge Quality, CAD/CAM

Selection of Optimal Superfinishing Parameters, Biju Varghese, Stephen Malkin, v2, n2, 2000, pp124-130

This paper is concerned with the selection of optimal superfinishing conditions. During superfinishing of cylindrical surfaces, an axially oscillating abrasive stone is pressed against a rotating workpiece. Experimental results are presented that show the effect of contact pressure, process kinematics, and grit size on superfinishing behavior. An optimal contact pressure is found at which the removal rate is maximized. The ratio of axial oscillation frequency to workpiece rotational frequency should be selected so as to avoid integer values, which result in low stock removal, and half values, which can lead to lobe formation. Finer grit stones provide smoother surface finishes but less stock removal; therefore, the grit size selected should be only fine enough to generate the required surface roughness.

Keywords: Superfinishing, Finishing, Abrasives, Optimization

A Postprocessor Based on the Kinematics Model for General Five-Axis Machine Tools, Chen-Hua She, Rong-Shean Lee, v2, n2, 2000, pp131-141

This paper presents a novel concept to describe the three types of five-axis machine tools by a generalized kinematic structure. A generic postprocessor capable of converting the cutter location (CL) data to machine control data was developed based on the generalized kinematics model of five-axis machine tools. The machine tool's form-shaping function matrix is derived according to the homogeneous coordinate transformation matrix and the kinematic parameters characterizing the configuration of general five-axis machine tool. The analytical equations for NC data are determined by equating the CL data matrix and the form-shaping function matrix. A trial-cut experiment on a typical five-axis machine tool and the verification on the coordinate measurement machine demonstrates the effectiveness of the proposed scheme. The algorithm proposed here can facilitate determination of the postprocessors for various five-axis machine tools more systematically.

Keywords: Five-axis, Postprocessor, Cutter Location Data, Form-shaping Function, Coordinate Transformation Matrix

Journal of Manufacturing Processes Volume 2, Number 3, 2000

Effect of Capacitor Discharge Welding on Single-Crystal Metals, Brian K. Paul, Wiwat Thaneepakorn, Rick D. Wilson, v2, n3, 2000, pp143-150

The objective of this study was to investigate the use of capacitor discharge welding (CDW) as a suitable tech-

1999-2002 abstract and keyword index

nique for joining metal single crystals by studying the effect of CDW on the microstructure of single-crystal copper. According to solidification theory, single-crystal formation requires high thermal gradients and moderate solidification rates. Therefore, an initial analysis was performed to determine if single-crystal CDW would result in a single-crystal microstructure. Joints were made using samples with joining surfaces at 0 deg, 15 deg, 30 deg, and 45 deg to the (111) crystal plane. Results show that single-crystal copper can be joined using CDW without the formation of voids and grain boundaries at the weld centerline. Average etch-pit densities after CDW are lower than those reported in the literature for single-crystal copper, suggesting minimal microstructural disruption. Crystal orientation does not seem to have any effect on fusion zone thickness or etch-pit density. Further work is needed to evaluate the effect of crystal orientation on void content in single-crystal copper welds made by CDW.

Keywords: Capacitor Discharge Welding, Single Crystal, Copper, Welding, Magnetostrictive Materials

Energy Partition and Cooling During Grinding, Changsheng Guo, Stephen Malkin, v2, n3, 2000, pp151-157

High temperatures in grinding can cause thermal damage to the workpiece. This paper presents an overview of quantitative methods to calculate grinding temperatures and the energy partition to the workpiece. It is shown that the energy partition, and consequently the grinding zone temperature, depends on the type of abrasives, fluid application conditions, and grinding process parameters. For regular grinding with conventional aluminum-oxide abrasive wheels, the energy partition typically ranges from 60% to 85%. However, for creep-feed grinding with slow work speeds and large depths of cut, cooling by the fluid at the grinding zone reduces the energy partition to less than 5%. For grinding with cubic boron nitride (CBN) superabrasive wheels, the energy partition is about 20% due to the high thermal conductivity of the CBN abrasive. However, this may be reduced from 8% to 5% for grinding with porous vitrified CBN wheels at high removal rates due to the combined effect of the high thermal conductivity of CBN abrasive and cooling by the fluid at the grinding zone.

Keywords: Grinding, Thermal, Cooling, Temperature

A New Approach to Predicting Forming Limits of Steel Sheet, S.G. Xu, K.J. Weinmann, v2, n3, 2000, pp158-166

A yield criterion utilizing five independent material parameters for representing the yield locus was proposed by Hill in 1993. This paper describes an attempt to analyze forming limits of aluminum-killed (AK) steel sheet metal based on this criterion in conjunction with the M-K approach. Comparison of the predicted results with experimental data indicates that localized necking can be characterized only to a limited extent. However, material properties do not remain constant, but are deformation history dependent. Inclusion of deformation-dependent parameters in the analysis demonstrates a significant positive influence on forming limits. Comparison of predicted results with the experimental data underscores that the consideration of history-dependent material properties can improve forming limit predictions considerably.

Keywords: Forming Limits, Sheet Steel, History-Dependent Material Properties

Analysis of No. 50 Taper Joint Stiffness Under Axial and Radial Loading, David M. Shamine, Yung C. Shin, v2, n3, 2000, pp167-173

This paper is concerned with the joint stiffness characteristics of the standard 7/24 taper interface. Experimental identification of joint stiffness parameters is performed on No. 50 tapers, using a special test setup, by implementing a frequency response function (FRF) based method for joint parameter identification, in conjunction with finite element modeling of the substructure. The effects of axial and radial loading as well as taper wear on the taper joint stiffness are examined. It is shown that taper joint stiffness nonuniformly increases with axial preloading and decreases with radial loading. Validation of the identified stiffness values is given by comparing the predicted natural frequencies of the taper assembly with experimentally measured values.

Keywords: Tapers, Joint Stiffness, Machine Tool Dynamics, System Identification, Finite Element Modeling of Tapers

Measurement Error Reduction in Automated Inspection of Free-Form Surfaces Defined by Cubic B-Spline, G. Lee, J. Mou, v2, n3, 2000, pp174-186

Historically, inspection data were used to determine whether or not a manufactured part met specifications. If the part did not meet specifications, it was reworked or scrapped. Now, inspection devices like coordinate measuring machines (CMMs) can provide data about how far a part is in or out of tolerance. The data are now being used to make manual adjustments to machining offsets and process parameters. However, the quality and reliability of many inspection processes are contaminated by various measurement errors. One of the prominent sources for measurement errors is due to the imperfection

1999-2002 abstract and keyword index

of a measuring device and the compound effect of its imperfection with geometric characteristics of a measured feature. To ensure the quality and reliability of any inspection process, measurement errors need to be identified and reduced by minimizing the effect of the compound errors. If this can be done, the quality of collected data can be enhanced and a more meaningful analysis result can then be drawn. In this paper, the issues of measurement error identification and reduction for machine calibration and dimension measurement, when dealing with uniform bicubic B-spline surface features are discussed. Analytical models are derived to first assess and then decouple the compound effect of both types of errors. Finally, case studies are used to illustrate the application and the effectiveness of the derived models in assessing and decoupling the compound effect and thus reducing the measurement errors.

Keywords: Automated Inspection, Compound Measurement Error, Error Reduction, Product Quality

Turning of Hardened Steels, R. Sood, C. Guo, S. Malkin, v2, n3, 2000, pp187-193

An investigation is reported of the face turning process for machining a hardened bearing steel using CBN cutting tools. Studies were made of the specific energy, the chips generated, the tool inserts used, and the machined surfaces. The specific cutting energy was found to be directly related to the maximum undeformed chip thickness, which is attributed to the plowing at the engaged cutting edge. Most of the chips generated were saw-toothed, which can account for the relatively large chip area ratios measured. The measured surface roughness and the ratio of 10 point to arithmetic average roughness, R_z/R_a, were comparable to their predicted ideal values for rougher surfaces with larger feeds, but the values tended to become progressively bigger for smoother surfaces with smaller feeds. The incidence of white layer generation decreased with a sharp tool at faster cutting speeds.

Keywords: Turning, White Layer, Energy, CBN

Clamping Fault Detection in a Fixturing System, J.H. Yeh, F.W. Liou, v2, n3, 2000, pp194-202

When a workpiece is located and clamped in a fixture, the dynamic response can be used to characterize its corresponding clamping condition. When the contact condition between the workpiece and the fixture is changed, the system response frequency will change accordingly. The identification of insufficient clamping forces is investigated in this study. This paper also presents the modeling and analysis of the contact condition between fixtures and components in a modular fixturing system. Analytical models were obtained using the finite element approach. Virtual spring elements used to model the dynamic effect of surface contact in the model, and the estimation of the virtual spring constants is also presented. Experimental results are compared with the analytical predictions.

Keywords: Fault Detection, Fixturing System, Contact Modeling, FEM, Experiment

Journal of Manufacturing Processes Volume 2, Number 4, 2000

A Study of the Optimization of Sheet Metal Drawing with Active Drawbeads, R. Li, M.L. Bohn, K.J. Weinmann, A. Chandra, v2, n4, 2000, pp205-216

An experimental study is described in which active drawbead technology is used to attempt to optimize the sheet metal forming process. Oval AA 6111-T4 panels were drawn in a series of tests using various drawbead trajectories to establish the feasibility of the approach. The selection of drawbead trajectory was shown to have a dramatic effect on maximum attainable draw depth at fracture. Increasing drawbead penetration from zero to 5 mm in the early stages of the drawing process and retracting midway through the draw resulted in a 40% increase in draw depth compared to using a fixed 5 mm penetration. In the second part of the investigation, active drawbead technology was used to study its effect on highly nonsymmetric panel forming. Drawing limit curves in terms of drawbead depth versus blankholder forces (BHF) were plotted, and different drawbead trajectories tested to determine an optimal drawbead trajectory scheme. A corresponding finite element model was also created. The results of strain path analysis successfully support the experiments.

Keywords: Sheet Formability, Drawbeads, Deep Drawing, Drawing Forces

Stability Analysis of Chatter on a Tandem Rolling Mill, Pei-Hua Hu, Kornel F. Ehmann, v2, n4, 2000, pp217-224

Accurate prediction of the onset of chatter is difficult in designing and operating a rolling mill. Both the lack of precise rolling process models and analytical methods for the investigation of mill stability have forced designers and users to rely on experience and trial and error, which are time consuming and cost demanding. A comprehensive rolling process model is introduced to form the foundation of chatter analysis that includes a range of possi-

1999-2002 abstract and keyword index

ble process variations. Analytical chatter models for both single and multiple-stand rolling mills are constructed that account for interactions between mill structure and rolling process, as well as between adjacent stands. Stability analysis is performed to formulate criteria for rolling mill design and operation. Finally, simulations and experiments are presented to verify some basic components of the rolling process model that constitute the proposed chatter models.

Keywords: Sheet Rolling, Rolling Dynamics, Rolling Chatter, Rolling Stability

An Approach to Theoretical Modeling and Simulation of Face Milling Forces, X.P. Li, H.Q. Zheng, Y.S. Wong, A.Y.C. Nee, v2, n4, 2000, pp225-240

A new approach to theoretical modeling and simulation of face milling forces is presented. The present approach is based on a predictive machining theory in which machining characteristic factors in continuous cutting with a single-point cutting tool can be predicted from the workpiece material properties, tool geometry, and cutting conditions. The action of a milling cutter is considered as the simultaneous work of a number of single-point cutting tools, and the milling forces are predicted from input data of workpiece material properties, cutter parameters and tooth geometry, cutting condition, cutter and workpiece vibration structure parameters, and types of milling. A predictive force model for face milling is developed using this approach. In the model, the workpiece material properties are considered as functions of strain, strain rate, and temperature. The ratio of cutter tooth engagement over milling is taken into account for the determination of temperature in the cutting region. Cutter runout is included in the modeling for the chip load. The relative displacement between the cutter and workpiece due to the cutter and workpiece vibration is also included in the modeling to consider the effect on the undeformed chip thickness. A milling force simulation system has been developed using the model, and face milling experimental tests have been conducted to verify the simulation system. It is shown that the simulation results agree well with experimental results.

Keywords: Metal Cutting, Milling, Modeling, Cutting Forces, Simulation, Vibration

An Experimental Investigation of Curved Surface-Straight Edge Hemming, Guohua Zhang, Hongqi Hao, Xin Wu, S. Jack Hu, Kris Harper, William Faitel, v2, n4, 2000, pp241-246

In this paper, an experimental investigation of the curved surface-straight edge hemming process is presented. Because hemming is the last stage of automotive panel forming operations, it directly influences the product surface, fitting, and joining qualities. Dimensional accuracy and precision in shape are two major concerns of hemmed parts, and these concerns are usually influenced by a large number of material, geometrical, and process factors. Planned experiments have been carried out according to a fractional factorial design method. Through regression analysis of the experimental results, the hemming quality indices, such as creepage, recoil, and radial springback, as well as hemming loads, can be expressed as a weighted sum of the input variable effects. In addition, the magnitude of each effect can be ranked from the most to the least significant. Using this information, hemming design guidelines can be developed for the optimization of hemming processes.

Keywords: Hemming, Design of Experiment (DOE), Sheet Metal Forming, Creepage, Recoil

A Comparison of Pin Actuation Schemes for Large-Scale Discrete Dies, Yong-Tai Im, Daniel F. Walczyk, Robert C. Schwarz, John M. Papazian, v2, n4, 2000, pp247-257

Reconfigurable discrete die tooling is attractive for reducing the lead time, initial costs, and recurring costs associated with stretch forming of sheet metal parts such as aircraft body panels and wing skins as well as automotive and marine components. Current tooling for the stretch forming process requires substantial lead time for fabrication and is inflexible and expensive. To develop discrete die tooling for stretch forming, three different discrete die designs have been proposed, and small-scale prototypes of each have been built. In this paper, the three designs are compared to each other in terms of performance criteria, including pin positioning accuracy and repeatability, setting speed, suitability for a production environment, fabrication costs, manufacturability and maintainability, and maximum forming load capacity. The advantages and disadvantages of each design are also discussed.

Keywords: Discrete Tooling, Pin Actuation, Reconfigurable Tooling, Stretch Forming

Bending of Titanium Sheet Using Laser Forming, Daniel F. Walczyk, Sameer Vittal, v2, n4, 2000, pp258-269

Laser forming, a novel manufacturing method for bending sheet metal first reported in 1985, has been investigated as an alternative to hot brake forming (industry standard) of titanium sheet parts for the aircraft industry. Laser forming involves scanning a focused or partially defocused laser beam over the surface of a titanium workpiece to cause localized heating along the bend line and angular deflection toward the beam. The main advantage that laser forming

1999-2002 abstract and keyword index

has over conventional brake forming is increased process flexibility. An experimental investigation of this process (primarily designed experiments) met the following objectives: identified the response variables related to change in geometry (bend angle) and material microstructure; characterized the influence of process variables (scanning speed, beam diameter, laser power) on these response variables; determined the degree of controllability over the process variables; and evaluated the suitability of laser forming for the aircraft industry (most important), all with respect to titanium sheet. It has been determined that laser forming with an Nd:YAG laser is a controllable, flexible manufacturing process for titanium sheet bending. Unfortunately, these advantages over traditional hot brake forming are overshadowed by the fact that, with regard to forming with titanium, laser forming is significantly slower and more labor and energy intensive and results in unacceptable material properties at the bend line according to aircraft industry standards. These findings cast doubt over the assertions of some researchers that laser forming may be a viable manufacturing process for parts made in small batches. Instead, it appears that it may be best suited for rapid prototyping of sheet metal parts.

Keywords: Laser Forming, Titanium Processing, Sheet Metal Forming, Hot Brake Forming

Technical Note: ***Effect of Tool Edge Geometry on Workpiece Subsurface Deformation and Through-Thickness Residual Stresses for Hard Turning of AISI 52100 Steel,*** Jeffrey D. Thiele, Shreyes N. Melkote, v2, n4, 2000, pp270-276

An experimental investigation was conducted to determine the effect of tool cutting edge geometry on workpiece subsurface deformation and through-thickness residual stresses for finish hard turning of through-hardened AISI 52100 steel. Polycrystalline cubic boron nitride (PCBN) inserts with "up-sharp" edges, edge hones, and chamfers were used as the cutting tools in this study. Examination of the workpiece microstructure reveals that large edge hone tools produce substantial subsurface plastic flow. Flow is not observed when turning with small edge hone tools or chamfered tools, and the workpiece microstructure appears random for these cases. Examination of through-thickness residual stresses shows that large edge hone tools produce deeper, more compressive residual stresses than are produced by small edge hone tools or chamfered tools. Explanations for these effects are offered based on assumed contact conditions between the tool and workpiece.

Keywords: Hard Turning, Cutting Edge Geometry, Subsurface Deformation, Residual Stresses

Journal of Manufacturing Processes Volume 3, Number 1, 2001

A Geometric Algorithm for Finding the Largest Milling Cutter, Zhiyang Yao, Satyandra K. Gupta, Dana S. Nau, v3, n1, 2001, pp1-16

This paper describes a new geometric algorithm to determine the largest feasible cutter size for 2-D milling operations to be performed using a single cutter. First is given a general definition of the problem as the task of covering a target region without interfering with an obstruction region. This definition encompasses the task of milling a general 2-D profile that includes both open and closed edges. Discussed next are three alternative definitions of what it means for a cutter to be feasible, with explanations of which of these definitions is most appropriate for the above problem. Then, a geometric algorithm is presented for finding the maximal cutter for 2-D milling operations, and the algorithm is shown to be correct.

Keywords: Computer-Aided Manufacturing, Process Planning, Cutter Selection for Milling

Vitrification Heat Treatment During the Manufacture of Corundum Grinding Wheels, M.J. Jackson, v3, n1, 2001, pp17-28

The development of a dissolution model for quartz in vitrified alumino-alkalisilicate bonding systems has been investigated. The model has been developed so that heat treatment cycles can be formulated that eliminate the harmful effects of residual quartz. The complete dissolution of quartz increases the efficiency of vitrified grinding wheels by reducing the likelihood of bond fracture. The loss of strength in the bonding system is caused by the displacive transformation of quartz at 573°C. The model describing the dissolution of quartz in alumino-alkalisilicate vitrified bonding systems was compared with experimental data using X-ray diffraction techniques. It was found that when the samples were isothermally heat treated, the residual mass fraction of quartz was found to be a function of time. When compared with experimental data, the model was found to be accurate for short periods of heat treatment. The model is of practical use for predicting the complete dissolution of quartz in vitrified bonding systems used for high-performance corundum grinding wheels.

Keywords: Abrasive Processes, Cutting Tools, Materials Properties, Materials Science, Process Modeling

An Optical Technique for Springback Measurement in Axisymmetrical Deep Drawing Operations, L. D'Acquisto, L. Fratini, v3, n1, 2001, pp29-37

Journal of Manufacturing Processes
Vol. 4/No. 2
2002

1999-2002 abstract and keyword index

In this paper, a measurement technique based on the shadow moiré method has been set up to evaluate the springback phenomenon in deep drawing operations. Two proper coefficients are introduced to quantitatively describe the investigated effect. In particular, the proposed technique is able to acquire the final profile of the drawn parts along one or more lateral contour, once extracted out from the dies, and compare such profile with the ideal one derived from the dies CAD geometry. The proposed technique has been applied to an axisymmetrical deep drawing operation, and, moreover, the influence of the blankholder force level and lubricating conditions has been taken into account. The obtained results have been compared both with a numerical prediction deriving from a commercial FEM code and measurements performed by a CMM.

Keywords: Sheet Metal Forming, Springback, Shape Measurement, FEM

Gas Dynamic Effects on Laser Cut Quality, Kai Chen, Y. Lawrence Yao, Vijay Modi, v3, n1, 2001, pp38-49

The presence of a gas jet plays an important role in laser cutting. Both the cutting efficiency and cut quality are very sensitive to gas pressure and nozzle standoff distance because of the complex nature of shock fronts and associated phenomena in a supersonic gas jet impinging on a workpiece. An idealized case is considered first, where the cut is assumed to be a circular hole directly underneath and concentric with the gas jet nozzle. A more realistic case of an axisymmetric nozzle impinging on a plate with a linear cut is considered next. Unlike the idealized case, the problem now is three-dimensional. Simple experiments to measure the through-kerf mass flow rate were carried out for both geometries. The two important forces exerted by the gas jet for melt ejection, namely, shear force and pressure gradient, show the same trend as that of the mass flow rate with varying gas pressure and standoff. The mass flow rate for the three-dimensional case shows the same behavior as that of the axisymmetric case, indicating the basic shock structures of the axisymmetric case are applicable to the real cutting cases. Laser cutting of mild steels under the corresponding conditions was performed, and the cut quality characterized by roughness, dross attachment, and recast layer thickness was analyzed. The deterioration of cut quality with the gas pressure and standoff is found to closely match reductions in through-kerf mass flow rate. It is thus verified that the shock structure of the gas jet and the associated mass flow rate have a direct impact on laser cutting as predicted.

Keywords: Gas Jet, Shock Structure, Laser Cutting, Quality

Detection of Weld Surface Porosity by Statistical Analysis of Arc Current in Gas Metal Arc Welding, E. Wei, D. Farson, R. Richardson, H. Ludewig, v3, n1, 2001, pp50-59

Fillet welds were made using the gas metal arc welding (GMAW) process with various parameter settings while arc voltage, arc current, and wire feed speed signals were recorded. Porosity was induced in some welds by excessive contact tip-to-work distance or low shielding gas flow rate. Welds were visually inspected for porosity and classified as porous or nonporous, and the arc current power spectral density (PSD) was calculated from the recorded values. Arc voltage, the 0 Hz arc current PSD component, arc current PSD components from 20 Hz to 40 Hz, and wire feed speed comprised the predictor group for linear discriminant analysis (LDA). This discriminator was called the "universal predictor" because it was designed to be independent of voltage and wire speed settings within a specified range. Arc current PSD components from 20 Hz to 40 Hz, wire feed speed, and the 0 Hz current PSD component comprised the predictor group for a second series of voltage-specific porosity detectors. It was found that the universal discriminator was about as accurate as discriminators formulated specifically for each voltage level.

Keywords: Linear Discriminant Analysis, GMAW, Quality Monitoring, Weld Porosity

Cooling Effects in Multiscan Laser Forming, Jin Cheng, Y. Lawrence Yao, v3, n1, 2001, pp60-72

For laser forming of sheet metal to become a practical production or rapid prototyping tool, multiple scans of the workpiece with the laser are necessary to achieve the required magnitude of deformation. Between consecutive scans, substantial waiting time is normally necessary for the workpiece to cool down so that a steep temperature gradient can be reestablished in the next scan. This paper first experimentally and numerically examines the effect of forced cooling on single-scan laser forming processes. Cooling effects under various conditions, including different laser power, scanning speed, nozzle offset, and cooling air pressure, are investigated. Cooling effects on microstructure change and other mechanical properties, including strength, ductility, and hardness, are also examined. A focus is to investigate the cooling effect on the deformation mechanism, including competing effects on temperature and flow stress. The investigation on multiscan laser forming shows forced cooling has the potential to significantly reduce the total forming time while having no undesirable effects on microstructure change and other mechanical behavior. Cooling in the buckling

1999-2002 abstract and keyword index

mechanism dominated laser forming process is also considered. The established numerical model for laser forming with forced cooling provides greater insights into the cooling effects on the deformation mechanism, helps predict such effects on final dimensional accuracy and mechanical properties, and can be extended to optimize the multiscan laser forming process.

Keywords: Laser Forming, Forced Cooling, Finite Element Method, Microstructure, Rapid Prototyping

Journal of Manufacturing Processes Volume 3, Number 2, 2001

Numerical and Experimental Investigation of Convex Laser Forming Process, Wenchuan Li, Y. Lawrence Yao, v3, n2, 2001, pp73-81

Laser forming is a flexible sheet metal forming technique using laser-induced thermal deformation to shape sheet metal without hard tooling or external forces. Concave laser forming can be readily achieved, while convex forming may occur through buckling, but the buckling direction heavily depends on the sheet surface and pre-strain condition. A new laser scanning scheme is postulated, by which convex forming can be effected insensitive to the abovementioned disturbances. The postulate is successfully validated by experimental and numerical results. The effect of the scanning parameters on the certainty of the convex forming, and dependencies of bend angle on Fourier number, laser power, and dimensionless velocity, are further investigated experimentally and numerically. The simulation results are in agreement with experimental observations. The numerical simulation model developed is also used to study the transient temperature, stress state, and strain state and to provide further insight into the convex forming process.

Keywords: Laser Forming, Nontraditional Manufacturing, Sheet Metal, Finite Element Analysis,

Regenerative Effect in Rolling Chatter, Pei-Hua Hu, Kornel F. Ehmann, v3, n2, 2001, pp82-93

The regenerative effect has been extensively studied in the field of metal cutting and recognized as one of the major causes of self-excited vibrations commonly known as chatter. In the presence of interactions between rolling mill stands, affecting the overall system dynamics, it will be shown that a tandem rolling mill may also become unstable due to a similar regenerative mechanism even though the individual stands are stable. In this paper, tandem mill stability will be investigated, in terms of the regenerative effect, using a multistand chatter model that incorporates a homogeneous process model and a mill structural dynamics model. Finally, simulation results will be presented to demonstrate the effects of regeneration on a three-stand tandem mill.

Keywords: Rolling Dynamics, Rolling Chatter, Regenerative Chatter, Rolling Stability,

Effect of Layer Thickness and Orientation Angle on Surface Roughness in Laminated Object Manufacturing, Brian K. Paul, Vinay Voorakarnam, v3, n2, 2001, pp94-101

The laminated object manufacturing (LOM) process is a freeform fabrication process used to produce wood-like prototypes and patterns for manufacturing processes such as sand casting. Therefore, surface roughness is an important factor in the utility of LOM prototypes. This study investigated the source of surface roughness in the LOM process to offer insight into the in-process control of surface roughness. A full-factorial experiment was performed to investigate the effect of layer thickness and orientation angle on the center-line average surface roughness of LOM prototypes. Results show orientation angle and paper thickness to be statistically significant. Further, the nature of surface roughness in LOM was found to be different than the nature of surface roughness in other freeform fabrication processes, such as sterolithography. Overall, this study indicates that the in-process control of prototype surface roughness may be possible in LOM by gaining greater control of the working distance during processing.

Keywords: Rapid Prototyping, Freeform Fabrication, Layered Manufacturing, Laminated Object Manufacturing, Surface Finish, Surface Roughness Model,

Rounding and Lobe Formation During Superfinishing, Biju Varghese, Stephen Malkin, v3, n2, 2001, pp102-107

An investigation is reported on rounding and lobe formation during external cylindrical superfinishing. A model was developed to simulate the instantaneous stock removal and the resulting workpiece profile in terms of the kinematics of the superfinishing process. The simulation predicts a lobing phenomenon when operating at half ratios of axial stone oscillation frequency to workpiece rotational frequency when abrasive tracks during successive workpiece rotations are completely out of phase, and minimal removal when this frequency ratio is an integer value such that successive abrasive tracks are in phase and do not intersect each other. The occurrence of lobes at half frequency ratios and reduced stock removal at whole frequency ratios were experimentally verified.

Keywords: Superfinishing, Lobing, Roundness

Journal of Manufacturing Processes
Vol. 4/No. 2
2002

1999-2002 abstract and keyword index

Rapid Prototyping by Laser Foil Bonding and Cutting: Thermomechanical Modeling and Process Optimization, Glory Hardjadinata, Charalabos C. Doumanidis, v3, n2, 2001, pp108-119

This paper introduces a new solid freeform fabrication technology based on successive joining of thin metal foils by laser spot welding, followed by laser cutting of each layer contour. This technology was implemented in the laboratory using a robotic Nd:YAG laser station with optical fiber transfer, and the optimal bonding and cutting conditions were determined experimentally for steel prototypes. A flexible thermomechanical finite element model of the process was established, with its boundary conditions calibrated and its predictions verified by pyrometry and profilometry measurements. This numerical model was used to study the layer deformation due to thermal gradients and to develop weld sequencing, cycle timing, and in-process heat treatment methods for minimization of warping distortions and residual stresses. This new rapid manufacturing technology can fabricate high-strength, high-density multi-metal parts and metal-matrix composites as well as internal functional structures with encapsulated active components.

Keywords: Rapid Prototyping, Laser Processing, Finite Elements, Thermal Distortion, Residual Stresses

Thermal Error Modeling of a Horizontal Machining Center Using Fuzzy Logic Strategy, Jin-Hyeon Lee, Jae-Ha Lee, Seung-Han Yang, v3, n2, 2001, pp120-127

Thermally induces errors originating from machine tool errors have received significant attention recently because high speed and precise machining is now the principal trend in manufacturing processes using CNC machine tools. The performance of a thermal error compensation system basically depends on the accuracy and robustness of the thermal error model. This paper presents a thermal error model using a fuzzy logic strategy, which does not require any complex procedure such as multiregression or information about the characteristics of the plant. Accordingly, the proposed modeling method can be applied to any type of CNC machine tool as the error model parameters are only calculated mathematically, plus the error model provides good accuracy and robustness.

Keywords: Thermal Error, Fuzzy Logic Model, Linear Regression Model, Engineering Judgment Model, Robustness

Microscale Laser Shock Processing—Modeling, Testing, and Microstructure Characterization, Wenwu Zhang, Y. Lawrence Yao, v3, n2, 2001, pp128-143

This paper reports modeling improvements for microscale laser shock processing (LSP), fatigue testing of laser shock processed copper and nickel, and microstructure characterization of the processed materials. Plasma expansion is modeled as laser-supported combustion wave, and radial, and axial expansions are considered. Stress/strain analysis is extended to three dimensions and takes into account finite geometry, which again is important for microscale LSP. Tests are designed to demonstrate that microscale LSP can improve fatigue performance of the materials while offering a level of flexibility. The influence of LSP on the microstructures of the materials is studied quantitatively using the orientation imaging microscope (OIM) technique, and grain size, texture, and subgrain structures are analyzed.

Keywords: Microscale Laser Shock Processing, Laser-Supported Combustion Wave, Orientation Imaging Microscope (OIM), Stress/Strain Analysis, Fatigue,

Journal of Manufacturing Processes Volume 4, Number 1, 2002

Robotic Manipulation of Highly Irregular Shaped Objects: Application to a Robot Crucible Packing System for Semiconductor Manufacture, Vivek A. Sujan, Steven Dubowsky, Yoshiaki Ohkami, v4, n1, 2002, pp1-15

The basic technology for a robotic system is developed to automate the packing of polycrystalline silicon nuggets into a fragile fused silica crucible in Czochralski (melt pulling) semiconductor wafer production. The highly irregular shapes of the nuggets and the packing constraints make this a difficult and challenging task. To address this task, key research areas are identified, developed, and integrated. In this system, nuggets are grasped by a three-cup suction gripper and manipulated with a seven-degree-of-freedom SCARA manipulator. An optical 3-D vision system, based on active laser triangulation, measures nugget and crucible profiles. A model-free Virtual Trial and Error packing algorithm determines optimal nugget placement in real time. A hybrid position-force control scheme has been implemented and tested for physical nugget placement. The simulation and laboratory tests show that the system has the capabilities of meeting high production rates, achieving high process constraints, and maintaining cost effectiveness that exceed levels obtained with manual packing. The results suggest that model-less robotic sensor control systems can be effective in manufacturing applications. The key contribution of this paper is to show that robot systems

1999-2002 abstract and keyword index

can be effectively used to manipulate highly irregular shaped objects in the context of real commercial manufacturing processes.

Keywords: Irregular Object Robot Manipulation, Bin Packing, Semiconductor Manufacturing

Conceptual Design of Machine Tool Interfaces for High-Speed Machining, Bernd Bossmanns, Jay F. Tu, v4, n1, 2002, pp16-27

High-speed machining is a promising technology to drastically increase productivity and product quality. However, conventional machine tool design often cannot meet stringent requirements needed to overcome various problems brought about by high-speed rotations. One particularly critical issue is how to hold an exchangeable tool rigidly during high-speed rotations. For this purpose, several new standards of tool interfaces between the toolholder and the spindle nose have been proposed. However, it has become increasingly difficult to choose among various competing interface standards or even different variations within a common standard. This issue is further complicated because many machine tool builders also offer various proprietary modifications to the common standards. Furthermore, there is also a need to develop new tool interfaces or modifications if existing standards are not satisfactory. The objective of this paper is to provide a systematic approach that can assist in conceptual design of machine tool interface for high-speed machining. This conceptual design methodology can also be used to select appropriate interface designs from various competing alternatives that exist today. Two embodiment concepts for high-speed end milling are developed as a case study based on the proposed conceptual design methodology. It is shown that the proposed design methodology can assist systematic design decision making and sound reasoning of the design choice.

Keywords: Tool Interface, Tool Taper, Toolholder, Spindle, High-Speed Machining

Geometry Regulation of Material Deposition in Near-Net Shape Manufacturing by Thermally Scanned Welding, Yong-Min Kwak, Charalabos C. Doumanidis, v4, n1, 2002, pp28-41

This paper introduces a thermally scanned material deposition control method for near-net shape manufacturing of metal parts by welding. To eliminate thermal distortion and the required intermediate layer milling steps, and to control the material structure, plasma-arc scan welding under infrared pyrometry sensing regulates the temperature field by providing in-process heat treatment of the part. In laboratory tests, the material is simultaneously deposited by a gas metal arc welding torch, with monitoring of the weld profile by two laser stripe profilometers. These sensors provide measurements of the bead width for its feedback control by modulation of the wire feed. To compensate for measurement delays, real-time prediction by a deposition model is employed, with its parameters identified during the process. Preview of the geometric surface irregularities in front of the deposition is used as feedforward to ensure the desired layer deposition patterns in adjacent beads. The performance of this bead-size control scheme is assessed experimentally on a robotic laboratory station, and applications of the thermally scanned material deposition technique are explored in rapid manufacturing of customized metal products.

Keywords: Near-Net Shape, Rapid Manufacturing, Scan Welding, Feedback Control, Rapid Tooling

Evaluation of Supersonic Nozzles for Laser Micromachining of High-Speed Steels, M.J. Jackson, M.D.H. Gill, A.H. Khan, W. O'Neill, v4, n1, 2002, pp42-51

The use of gas jets during laser micromachining processes plays an important role in determining machining efficiency. Gas pressures and nozzle stand-off distances are extremely important process parameters when one considers the nature of shock waves in a gas jet impinging on the surface of a workpiece material. A second-order method of characteristics (MOC) algorithm was used to determine the flow field and wall contour for supersonic axisymmetric, minimum-length micronozzles with a straight sonic line. Contours for axisymmetric supersonic micronozzles were predicted with stagnation pressures in the region of 8 atmospheres. These profiles were then tested using a compressible computational fluid dynamic (CFD) code. CFD codes were also used to model pressure distributions and the occurrence of shock wave formation during laser micromachining applications. This paper shows how computational techniques have been used to develop axisymmetric, straight, sonic-line, micro minimum-length nozzles with a throat diameter of less than 300 μm that are suitable for laser micromachining applications.

Keywords: Micromachining, Laser Materials Processing, Nozzle Design, Gas Jets

Optimal and Robust Design of Laser Forming Process, Chao Liu, Y. Lawrence Yao, v4, n1, 2002, pp52-66

The laser forming process of sheet metal has been extensively analyzed, but few attempts have been made in the area of process design. The task of the process design in the laser forming of sheet metal is to determine a set of

1999-2002 abstract and keyword index

parameters, including laser scanning paths, laser power, and scanning speed, given a prescribed shape. Response surface methodology is used as an optimization tool. The propagation of error technique is built into the design process as an additional response to be optimized via desirability function and hence make the design robust. Focusing on a class of shapes, the design scheme is applied progressively in four cases in which issues such as a large number of design variables are properly addressed.

Keywords: Optimal Design, Response Surface Methodology, Propagation of Error, Laser Forming

Existence and Effects of Overlap Factors Greater than Unity and Less than Zero, William J. Endres, O. Burak Ozdoganlar, v4, n1, 2002, pp67-76

A geometric model of the dynamic chip area for processes that employ corner-radiused tools is used to show how the resulting mathematical expressions for overlap factor lead to values outside the traditional range of zero to unity. The mathematical expressions are geometrically interpreted through schematics of the process geometry. The orthogonal cutting stability solution shows that results are identical for positive and negative overlap factors of the same magnitude. The effects of overlap factor outside the traditional range are shown; however, it is shown that coupling overlap factor to other directional factors, through the depth of cut (the dependent variable), makes it impossible to interpret stability results based on the overlap factor concept alone. Specific examples show that while overlap factor often exceeds unity for corner-radiused tools, reaching extreme values that approach infinity does not seem to occur due to the strong dependence on the depth of cut—the dependent variable of the stability analysis.

Keywords: Machining Stability, Overlap Factor, Turning, Chatter

Design and Test of a Reconfigurable Forming Die, Edwin Haas, Robert C. Schwarz, John M. Papazian, v4, n1, 2002, pp77-85

Reconfigurable tooling is an attractive prospect for aerospace sheet metal forming because many different part shapes must be produced in small numbers. This paper describes the design and test of a particular type of "discrete-die" reconfigurable tool. The discrete-die concept involves using the ends of densely packed rod-shaped elements as the working surface of the die. The rod-shaped elements are reconfigured manually or automatically to change the shape of the die. Numerous mechanical schemes can be employed to move the elements: this paper describes the use of a shaft-driven lead screw concept. The input shaft turns continuously, and each pin's position is controlled by the engagement of an individual clutch. The required design parameters were developed using a combination of theory and experiment, and a laboratory-scale working prototype device was built and tested. The design parameters included an evaluation of the suitability of open-loop pin-position control based only on time, an evaluation of the torque capacity, engagement time, and reliability of the clutches, and the development of design loads. Experience in construction of the prototype showed that the design concept was sound but that significant enhancements to the control system would be required in a full-scale device.

Keywords: Sheet Metal Forming, Reconfigurable Dies, Metal Forming, Tooling for Metal Forming, Design of Reconfigurable Tooling

Journal of Manufacturing Processes Volume 4, Number 2, 2002

The Effects of Corner Radius and Edge Radius on Tool Flank Wear, William J. Endres, Raja K. Kountanya, v4, n2, 2002, pp89-96

The use of cutting tools with a honed edge radius to protect the cutting edge from chipping is ever increasing. The basic understanding of the fundamental cutting mechanics in the presence of an edge radius is increasing as well. The present state of knowledge leads one to question how edge-radiused tools behave under conditions that are more practical than straight-edged orthogonal cutting. Presented here is a study of the interaction of edge radius with corner radius, the latter of which is commonly seen in turning, boring, and face milling processes. Turning test data show that tool flank wear can be minimized for up-sharp tools by using a moderate corner radius. For tools with an edge radius, a wear-minimizing corner radius still exists but is higher than for up-sharp tools. Physical interpretations of these direct and interaction effects are presented.

Keywords: Flank Wear, Orthogonal Cutting, Edge Radius, Hone, Machining Force

Design of Profile Ring Rolling by Backward Simulation Using Upper Bound Element Technique (UBET), Adel Alfozan, Jay S. Gunasekera, v4, n2, 2002, pp97-108

The upper bound element technique (UBET) is used to determine the optimum intermediate shape for profile

1999-2002 abstract and keyword index

ring rolling using backward simulation. The lowest energy rate is the key issue in achieving the optimal intermediate shape as well as the backward simulation of the process. The plastic flow of material in ring rolling is assumed to be a sequence of successive closed-die forging processes. The ring is divided into features, which provide an approximated profile consisting of a number of rectangular elements. The simulation of the profile ring rolling was tested with different profiles of rolls, and two such cases are presented here. The present method was validated using an experimental radial ring rolling mill designed and fabricated in the Dept. of Mechanical Engineering at Ohio University for the investigation of both cold and hot ring rolling processes. As the results show, this technique is capable of solving the backward simulation of profile ring rolling problems in a much shorter time compared to the finite element method (FEM), which cannot easily simulate profile ring rolling. Moreover, as an engineering tool, this approach can be applied effectively to the profile ring rolling process and can serve as a useful tool in industrial applications.

Keywords: Backward Simulation, Upper Bound Element Technique (UBET), Ring Rolling, Metal Forming

Modeling of X-Ray Fabrication of Macromechanical Structures, Y. Liu, P. Sheng, v4, n2, 2002, pp109-121

This paper evaluates the application of Lithographie, Galvanoformung, Abformung (LIGA) as a technique for fabricating millimeter to centimeter-scale mechanical components. The main focus of the work is an investigation of modeling approaches to estimate dimensional accuracy of complex profile features. Numerical models for X-ray exposure and an empirical model for polymethyl-methacrylate (PMMA) development are presented. Optical coordinate measurements are performed on two case studies associated with fabricating a planetary gear assembly: (1) a spider frame and (2) involute gear tooth profiles.

Keywords: X-Ray Lithography, Microfabrication, MEMS, Process Modeling, Error Characterization, Precision Manufacturing

Cryogenic Machining of Tantalum, Z.Y. Wang, K.P. Rajurkar, J. Fan, G. Petrescu, v4, n2, 2002, pp122-127

A new approach for the machining of tantalum is presented. The new approach is a combination of traditional turning and cryogenically enhanced machining (CEM). In the tests, CEM was used to reduce the temperatures at the cutting tool/workpiece interface, and thus reduces the temperature-dependent tool wear to prolong cutting tool life. The new method resulted in a reduction of surface roughness of the tantalum workpiece by 200% and a decrease of cutting forces by approximately 60% in experiments. Moreover, cutting tool life was extended up to 300% over that in the conventional machining.

Keywords: Tantalum, Cryogenic Turning, Tool Life

Composite Modeling and Analysis for Fabrication of FDM Prototypes with Locally Controlled Properties, L. Li, Q. Sun, C. Bellehumeur, P. Gu, v4, n2, 2002, pp129-141

Solid freeform fabrication (SFF) technologies have the ability to manufacture functional parts with locally controlled properties, which provides an opportunity for manufacturing a whole new class of products. To certain extent, fused deposition modeling (FDM) has the potential to fabricate parts with locally controlled properties by changing deposition density and deposition orientation. To fully exploit this potential, this paper reports a study of the materials, the fabrication process and the mechanical properties of FDM prototypes. Theoretical and experimental analyses of mechanical properties of FDM processes and prototypes were carried out to establish the constitutive models. A set of equations is proposed to determine the elastic constants of FDM prototypes. The models are then evaluated by experiments. An example of FDM prototype with locally controlled properties is provided to demonstrate the ideas.

Keywords: Solid Freeform Fabrication, Fused Deposition Modeling, Locally Controlled Properties, Composites, and Composite Mechanics

Specific Grinding Energy Causing Thermal Damage in Helicopter Gear Steel, John E. Mayer, Jr., Angie H. Price, Ganesh K. Purushothaman, Arun Kumar Dhayalan, Marc S. Pepi, v4, n2, 2002, pp142-147

Thermal damage (burn) in carburized and hardened helicopter gear steel caused by grinding was investigated. Excessive grinding temperatures cause grinding burn and result in excessive scrap or reduced fatigue life. Vasco X2M gear steel, used in helicopters, was prepared and heat-treated by a research partner, U.S Army. Grinding tests were conducted on this steel. Nital etching was used to detect grinding burn. Model was established to predict onset of thermal damage for Vasco X2M steel based on specific grinding energy determined from grinding force measurements. The model was compared to results published for other steels. A control strategy is suggested based on the model to avoid grinding burn.

Keywords: Grinding, Thermal Damage, Gear Steels

Journal of Manufacturing Processes
Vol. 4/No. 2
2002

1999-2002 abstract and keyword index

Technical Note: ***An Investigation of Selective Coloring with 3-D Laser Printing,*** Denis Cormier, James Taylor, Harvey West, v4, n2, 2002, pp148-152

This paper reports on preliminary results involving an experimental rapid prototyping process known as 3-D laser printing. The system builds parts by repeatedly laser printing thermoplastic cross-sectional "slice" images of a part one on top of the next. With each new layer, the total build thickness increases until the part is complete. An interesting extension to this system involves the use of a color print engine to produce selectively colored parts. Conventional rapid prototyping processes generally do not allow this sort of selective coloring. Initial results indicate that the system has considerable potential and warrants continued investigation.

Keywords: Rapid Prototyping, Selective Coloring, Electrophotography, 3-D Laser Printing

1999-2002 AUTHOR INDEX

Journal of Manufacturing Processes Volumes 1-4, 1999-2002

Alfozan, Adel, v4, n2, 2002, p97
Aspinwall, D.K., v2, n2, 2000, p108

Bellehumeur, C., v4, n2, 2002, p129
Bohn, M.L., v2, n4, 2000, p205
Bossmanns, Bernd, v4, n1, 2002, p16

Cao, Jian, v2, n2, 2000, p100
Chandra, A., v2, n4, 2000, p205
Chang, T-C., v1, n1, 1999, p1
Chen, Kai, v1, n1, 1999, p43; v3, n1, 2001, p38
Cheng, Jin, v3, n1, 2001, p60
Chu, Chih-Hsing, v2, n2, 2000, p116
Cormier, Denis, v4, n2, 2002, p148

D'Acquisto, L., v3, n1, 2001, p29
Dewes, R.C., v2, n2, 2000, p108
Dhayalan, Arun Kumar, v4, n2, 2002, p142
Dornfeld, David, v2, n2, 2000, p116
Doumanidis, Charalabos C., v3, n2, 2001, p108; v4, n1, 2002, p28
Dubowsky, Steven, v4, n1, 2002, p1

Ehmann, Kornel F., v2, n4, 2000, p217; v3, n2, 2001, p82
Elkins, Kerry L., v1, n1, 1999, p18
Endres, William J., v4, n1, 2002, p67; v4, n2, 2002, p89

Faitel, William, v2, n4, 2000, p241
Fan, J., v4, n2, 2002, p122
Farson, D., v3, n1, 2001, p50
Fassi, Irene, v2, n1, 2000, p1
Fratini, L., v3, n1, 2001, p29

Gill, M.D.H., v4, n1, 2002, p42
Gosselin, Clement M., v2, n1, 2000, p36
Grzesik, W., v2, n2, 2000, p79
Gu, P., v4, n2, 2002, p129
Guceri, Selcuk I., v2, n2, 2000, p88
Gunasekera, Jay S., v4, n2, 2002, p97
Guo, Changsheng, v2, n3, 2000, p151; v2, n3, 2000, p187
Gupta, Satyandra K., v3, n1, 2001, p1
Gweon, Dae-Gab, v1, n1, 1999, p31

Haas, Edwin, v4, n1, 2002, p77
Han, Guk-chan, v1, n1, 1999, p54; v1, n1, 1999, p62
Hao, Hongqi, v2, n4, 2000, p241
Hardjadinata, Glory, v3, n2, 2001, p108
Harper, Kris, v2, n4, 2000, p241
Ho, Min-Tse, v2, n1, 2000, p15
Hu, Pei-Hua, v2, n4, 2000, p217; v3, n2, 2001, p82
Hu, S. Jack, v2, n4, 2000, p241
Huang, Tian, v2, n1, 2000, p36
Hwang, Yean-Ren, v2, n1, 2000, p15

Ihlenfeldt, Steffen, v2, n1, 2000, p59
Im, Yong-Tai, v2, n4, 2000, p247

Jackson, M.J., v3, n1, 2001, p17; v4, n1, 2002, p42

Khan, A.H., v4, n1, 2002, p42
King, Calvin, v2, n1, 2000, p48
Koren, Yoram, v2, n1, 2000, p25
Kountanya, Raja K., v4, n2, 2002, p89
Kwak, Yong-Min, v4, n1, 2002, p28

Le, Xiaobin, v1, n1, 1999, p71
Lee, D.W., v2, n2, 2000, p108
Lee, G., v2, n3, 2000, p174
Lee, Jae-Ha, v3, n2, 2001, p120
Lee, Jin-Hyeon, v3, n2, 2001, p120
Lee, Rong-Shean, v2, n2, 2000, p131
Li, L., v4, n2, 2002, p129
Li, R., v2, n4, 2000, p205
Li, Wenchuan, v3, n2, 2001, p73
Li, X.P., v2, n4, 2000, p225
Lim, Dae-Cheol, v1, n1, 1999, p31
Lin, Rong-Shine, v2, n1, 2000, p25
Liou, F.W., v2, n3, 2000, p187
Liu, Chao, v4, n1, 2002, p52
Liu, Y., v4, n2, 2002, p109
Ludewig, H., v3, n1, 2001, p50

Malkin, Stephen, v2, n2, 2000, p124; v2, n3, 2000, p151; v2, n3, 2000, p187; v3, n2, 2001, p102
Mayer, John E., Jr., v4, n2, 2002, p142
Melkote, Shreyes N., v2, n4, 2000, p270
Modi, Vijay, v3, n1, 2001, p38
Molian, P.A., v1, n1, 1999, p1
Mou, Jong-I, v2, n1, 2000, p48; v2, n3, 2000, p174

1999-2002 author index

Na, Suck-joo, v1, n1, 1999, p54; v1, n1, 1999, p62
Nau, Dana S., v3, n1, 2001, p1
Nee, A.Y.C., v2, n4, 2000, p225
Neugebauer, Reimund, v2, n1, 2000, p59
Ng, E-G, v2, n2, 2000, p108
Nieslony, P., v2, n2, 2000, p79

Ohkami, Yoshiaki, v4, n1, 2002, p1
O'Neill, W., v4, n1, 2002, p42
Ozdoganlar, O. Burak, v4, n1, 2002, p67

Papazian, John M., v2, n4, 2000, p247; v4, n1, 2002, p77
Paul, Brian K., v2, n3, 2000, p143; v3, n2, 2001, p94
Pepi, Marc S., v4, n2, 2002, p142
Peterson, M.L., v1, n1, 1999, p71
Petrescu, G., v4, n2, 2002, p122
Pistor, Christoph M., v2, n2, 2000, p88
Price, Angie H., v4, n2, 2002, p142
Purushothaman, Ganesh K., v4, n2, 2002, p142

Rajurkar, K.P., v4, n2, 2002, p122
Richardson, R., v3, n1, 2001, p50
Ridgeway, Shannon, v2, n1, 2000, p67

Schwarz, Robert C., v2, n4, 2000, p247; v4, n1, 2002, p77
Shamine, David M., v2, n3, 2000, p167
She, Chen-Hua, v2, n2, 2000, p131
Sheng, P., v4, n2, 2002, p109
Shin, Yung C., v2, n3, 2000, p167
Song, Jing, v2, n1, 2000, p48
Sood, R., v2, n3, 2000, p187
Sturges, Robert H., v1, n1, 1999, p18
Sujan, Vivek A., v4, n1, 2002, p1
Sun, Q., v4, n2, 2002, p129

Taylor, James, v4, n2, 2002, p148
Thaneepakorn, Wiwat, v2, n3, 2000, p143
Thiele, Jeffrey D., v2, n4, 2000, p270
Tlusty, Jiri, v2, n1, 2000, p67
Tu, Jay F., v4, n1, 2002, p16

Varghese, Biju, v2, n2, 2000, p124; v3, n2, 2001, p102
Vittal, Sameer, v2, n4, 2000, p258
Voorakarnam, Vinay, v3, n2, 2001, p94

Walczyk, Daniel F., v2, n4, 2000, p247; v2, n4, 2000, p258
Wang, Jinsong, v2, n1, 2000, p36
Wang, Xi, v2, n2, 2000, p100
Wang, Z.Y., v4, n2, 2002, p122
Wei, E., v3, n1, 2001, p50
Weinmann, K.J., v2, n3, 2000, p158; v2, n4, 2000, p205
West, Harvey, v4, n2, 2002, p148
Whitehouse, David J., v2, n1, 2000, p36
Wieland, Frank, v2, n1, 2000, p59
Wilson, Rick D., v2, n3, 2000, p143
Wong, Y.S., v2, n4, 2000, p225
Wu, Xin, v2, n4, 2000, p241

Xu, S.G., v2, n3, 2000, p158

Yang, Seung-Han, v3, n2, 2001, p120
Yao, Y. Lawrence, v1, n1, 1999, p43; v3, n1, 2001, p38; v3, n1, 2001, p60; v3, n2, 2001, p73; v3, n2, 2001, p128; v4, n1, 2002, p52
Yao, Zhiyang, v3, n1, 2001, p1
Yardimci, M. Atif, v2, n2, 2000, p88
Yeh, J.H., v2, n3, 2000, p187

Zhang, Guohua, v2, n4, 2000, p241
Zhang, Wenwu, v3, n2, 2001, p128
Zheng, H.Q., v2, n4, 2000, p225
Ziegert, John C., v2, n1, 2000, p67